

Application of double electrode welding as the way to increase welding productivity of fillet welds of bridge structures

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Abstract. One of the ways to solve the task to increase productivity and obtain an enlarged leg in one pass is the use of two-electrode submerged arc welding (welding with a split electrode). When testing this welding method with respect to welding bridge metal structures, it was found that the quality of the welded joints and the productivity of the process substantially depend on the positioning of the electrodes relative to the groove. However, for the effective implementation of this method, a comprehensive study of its functionality for welding of bridge metal structures is necessary to conduct. An effective tool in solving such problems is physical and mathematical modeling, which allows without running a large number of experiments to study the features of the formation of fillet welds. To carry out this analysis, we used the previously developed physical and mathematical model of weld formation in single-arc submerged arc welding, added a description of the spatial position of the split electrode relative to the joint and defined the distribution of the heat flux and pressure of the double arc. It was found that the location of the electrodes with the lagging arc on the web provides better weld formation.

1. Introduction

In the recent years we can observe a dynamic development of bridge building in Russia. At the same time, three-dimensional welded metal structures manufactured in factories, which are then enlarged into bridge spans, are supplied to the bridge construction site. It should be noted, the main part of the welding works is in the manufacture of metal structures in workshop conditions, and when the metal structures are enlarged at the construction site, the volume of welding works is reduced. A special feature of bulk metal structures is the presence of a large number of extended welds (more than 2 m), Figure 1. The conducted analysis showed that the volume of welding of extended welds in the total volume of welding works is about 50–60%, while the fillet welds can make up from 40% to 70% of the total volume of welds.

Taking into account the specific nature of the operation of bridges (sharp changes in ambient temperature, the condition of soils, including marshy and permafrost, wind and variable dynamic loads from moving vehicles), strict requirements are imposed on the quality of welded joints. In this regard, welding modes, applied welding technologies, welding materials and equipment should ensure that welded joints are with the same mechanical properties as the base metal. In addition special attention



should be paid to the geometry of fillet welds, since it is the geometry of the transition zone from the weld to the base metal that determines the stress condition in the given structure zone and, therefore, affects the durability of the welded joint [1].



Figure 1. Road bridge element.

Within the permissible values of the parameters of the welding modes regulated by statutory instrument, the maximum productivity has actually been achieved. And today, one of the important production tasks in the manufacture of bridge structures is to increase productivity, it is also possible by obtaining a larger leg length in one pass.

2. Materials and Methods

Traditionally, fillet welds with a leg up to 8 mm are produced using single-arc automatic submerged arc welding in one pass, seams with a large leg for several passes in 2F position or in 1F position. To assess the need to improve traditional technologies or develop new ones at the first stage, it is necessary to estimate the possibility of obtaining the maximum leg under submerged arc welding with a consumable electrode of fillet welds.

An effective tool in solving such problems is physical and mathematical modeling, which allows, without carrying out a large number of experiments, to study the specific features of the formation of fillet welds under submerged arc welding [2, 3]. To simulate physical phenomena, an area was selected, that covers the welded edges and arc burning zones, melting of flux and metal, Figure 2. Modeling area includes: M is the base metal, E is the electrode, D is the welding arc, F is the flux, V is flux fumes, G is the molten flux, R is the solidified flux, L is the liquid metal, K is the solid-liquid metal, S is the weld metal, W – air. Internal interband surfaces are marked as intersections of the sets of points belonging to the corresponding zones. For example, the surface of the weld pool $Z_L(x, y)$ separating the weld pool L from the welding arc D , flux fumes V and molten flux G is marked as $L \cap (D \cup V \cup G)$. The sizes of the V , G , L , K zones and the location of the interface between them are unknown, and they must be determined during the simulation, depending on the results obtained when solving a system of equations describing the physical phenomena that occur during submerged arc welding.

The main differences between submerged arc welding from shielded gas arc welding are that the arc burns in a gas-vapor cavity arising from melting and evaporation of the flux. The second important feature is that the physical phenomena that determine the formation of the weld pool and weld, as noted in the work [4], occur in different environments. These features must be taken into account in the physical and mathematical model of the formation of the weld under submerged arc welding. The basis of the model is a system of equations of heat conductivity and equilibrium of the surface of the weld pool, in which the formation of the arc cavity is determined by the boiling isotherm of the flux under the influence of the arc column, heat transfer by flux fumes inside the arc cavity is taken into account, as well as the influence of the spatial position on the formation of the weld pool [5]. The numerical solution of the equations of the submerged arc welding of a fillet weld at a metal thickness

typical for bridge structures showed that when welding in 1F position, joint formation is made in one pass.

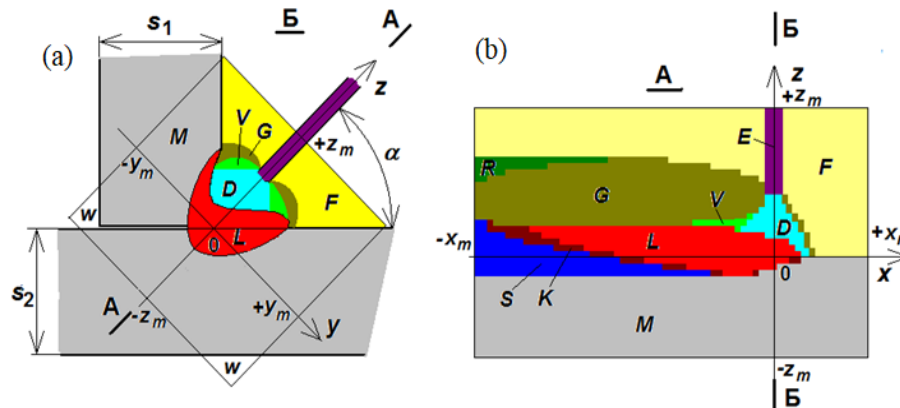


Figure 2. The structure of the chosen area to model the process of fillet welding.

Modeling showed that when welding a fillet weld in 2F position, unsatisfactory formation is possible due to runoff of liquid metal from a web. In this case, to obtain a high-quality weld seam, it is necessary to perform additional welding passages.

3. Results

To find out the maximum size of the leg, which is formed during welding in 1F position and in 2F position, with high-quality formation of a seam, we performed modeling of fillet welding of sheets with a thickness of 8 mm, a wire with a diameter of 2 mm and an arc current of 350 A, Figure 3. The welding speed and arc voltage were varied.

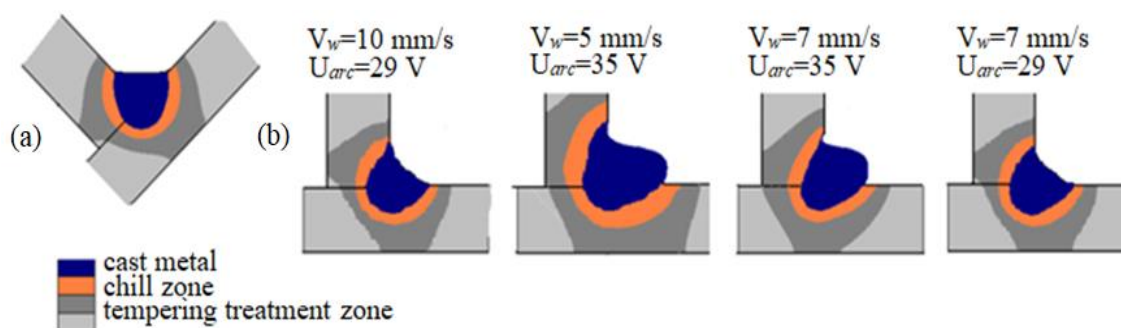


Figure 3. The result of computer simulation of the formation of the seam:
a) in 1F position b) in 2F position.

The studies confirmed the assumption that the existing technologies for single-arc submerged arc welding of fillet welds have already reached their maximum productivity. Obviously, it is possible to achieve a further increase in the productivity of the welding of fillet welds with the formation of legs of increased size only by using multi-arc and multi-electrode welding methods [6, 7]. According to the research [8] during the production of extended fillet welds, the use of two-electrode welding is effective, as it is easy to implement, especially in the conditions of existing production, and ensuring a consistently high quality of welded joints. Therefore, at the second stage of the research, the possibilities of two-electrode submerged arc welding of fillet welds (welding with a split electrode) were determined. A distinctive feature of two-electrode welding is the simultaneous heating of the welded seam with two electrodes with a common supply of welding current.

It is known that the quality of welded joints in two-electrode welding depends not only on the welding conditions, but also to a greater extent on the positioning of the electrodes relative to the

beveling. Shifting of the electrodes towards the flange or closer to the upper part of the beveling affects the likelihood of undercuts and sagging, the penetration depth, Figure 4 [8].

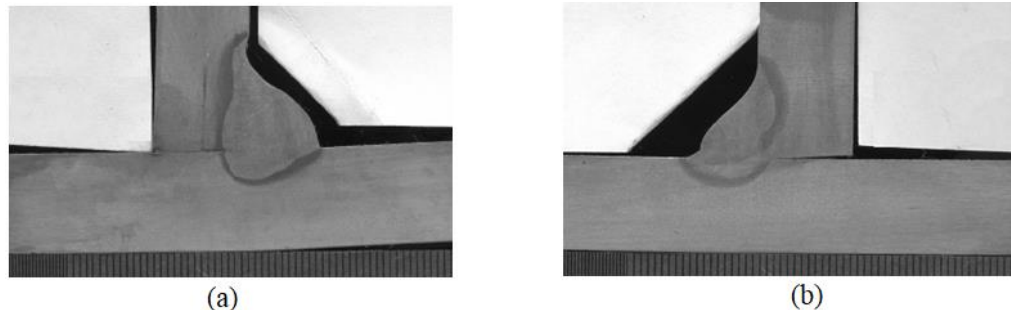


Figure 4. Macro sections of samples welded with a different arrangement of electrode wires relative to the axis of the seam: a) with shifting of the electrodes towards the flange; b) when the electrodes are closer to the upper part of the beveling.

In order to develop rational technologies for two-electrode welding of fillet welds and the necessary welding equipment for the industrial production of three-dimensional bridge metal structures, it is necessary to analyze technological parameters of the process of automatic two-electrode welding and the influence of electrode positioning on the formation of fillet welds; to develop a physical and mathematical model for the formation of fillet welds in two-electrode welding and to carry out computer engineering analysis of the influence of two-electrode welding parameters on the quality of welded joints and determine their optimal values.

To perform this analysis, we used the previously developed physical and mathematical model of weld formation in single-arc submerged arc welding added a description of the spatial position of the split electrode relative to the joint and defined the distribution of the heat flux and pressure of the double arc. Accordingly, additional parameters were introduced into the model: the distance g between the electrodes, the angle β between the surface of the electrodes and the direction of welding, and the distance r from the electrode to the midline of the joint. The influence of the angle α of inclination of the torch relative to the joint was also taken into account.

4. Discussion

Virtual studies of the process of welding with a split electrode in 2F position showed that the maximum leg of a fillet weld is achieved with the following process parameters: electrode wire with a diameter of 2 mm, feed rate of 23 mm/s, electrode stick-out of 25 mm, angle of inclination 45° to the horizon. The electrodes are located at a distance of 8 mm from each other, perpendicular to the plane of symmetry of the joint and the direction of welding. Welding mode: welding speed 10 mm/s, the total current of the split arc is 850 A, the voltage across the arcs is 29 V.

Figure 5 shows the result of computer simulation of the formation of the weld pool and a weld taking into account the temperature distribution at the joint, electrodes and flux when welding the T-joints of sheets of 10ChSND steel with a thickness of 14 mm by a split arc using a Sv-08G2S (analogy 13Mn6 – DIN, Germany) electrode wire with a diameter of 2 mm.

As a result of the simulation, it was determined that at a relatively close distance between the electrodes, a vapor-gas cavity common to both arcs and a single weld pool are formed. The arc length is about 3 mm, the total heat dissipation in the arc column is 12.7 kW. The power of heat release in the cathode spot was 6.8 kW, the power transferred by drops of electrode metal was 5.1 kW. The width of the weld pool is defined at 16.8 mm, the depth is 10.5 mm, and the length is 67 mm. However, with further augmentation, the melt of the weld pool drains from a web to a flange due to gravitational impact.

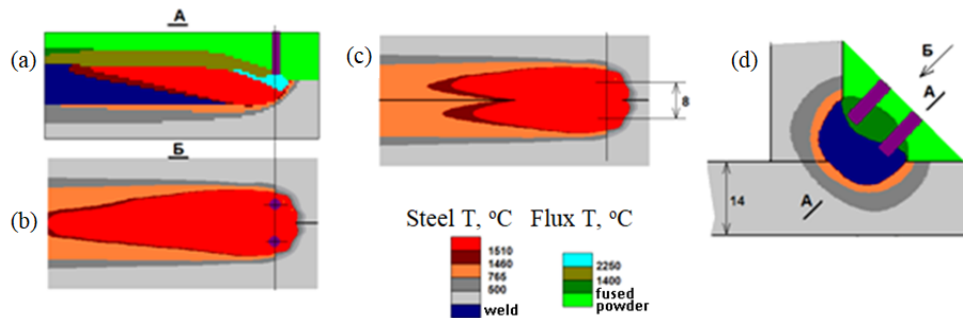


Figure 5. The modeling result of the temperature distribution during welding in 2F position:

- a) in a longitudinal section of the weld pool; b) on the surface of the 'metal-flux';
- c) on the initial surface of the sheets; d) calculated macro section.

For this welding option, a study was made of the influence of the angle β , which determines the location of the electrodes relative to the direction of welding. The alignment parameters of the electrodes relative to the joint: $\alpha = 45^\circ$, $g = 8$ mm, $r = -3$ mm. The simulation result is shown in Figure 6.

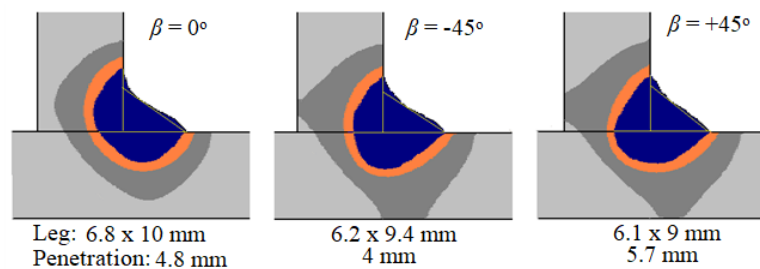


Figure 6. The simulation results at different β angles of the location of the electrodes relative to the joint.

It was determined that when the electrodes are placed on a line perpendicular to the direction of welding, a wide seam is formed with noticeable runoff of the melt from the web. For this reason, the size of the supporting leg on this web is noticeably reduced (up to 6.8 mm) with respect to the leg on a flange (10 mm). The penetration of the joint between the web and the flange (4.8 mm) does not reach half the wall thickness. When the arc moves forward on the web ($\beta = -45^\circ$) and, accordingly, the arc lags on the flange, the width and legs of the seam decrease, and the penetration depth increases, which is explained by the approach of the arcs to the plane of symmetry of the joint. However, only the penetration of the flange increases, and the penetration of the joint between the web and the flange decreases (4 mm). The melt runoff is less noticeable in comparison with the symmetrical arrangement of the electrodes, the difference of legs is also slightly reduced. When the arc on the wall moves backward ($\beta = +45^\circ$), at which the arc on the web lags behind the arc on the flange, the melt runoff and the difference of legs are noticeably reduced. Joint penetration increases significantly (5.7 mm).

Since of the arrangement with the arc lag on the web provides the best formation of the seam, further research of the influence of the parameters was performed for this option. Since the legs of the seam for this thickness are insufficient, we increased the distance between the arcs ($g = 12$ mm), Figure 7.

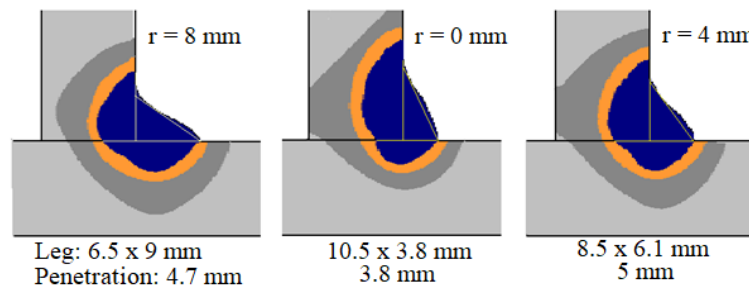


Figure 7. The simulation results at different location of the electrodes r relative to the joint and at different inclination angle α of the torch.

When the electrodes are placed on a line perpendicular to the direction of welding, a wide seam is formed with noticeable runoff of the melt from the web. For this reason, the size of the supporting leg on this web is noticeably reduced (up to 6.8 mm) with respect to the leg on a flange.

5. Conclusion

The research showed that the existing technologies for single-arc as well as double-electrode submerged arc welding of fillet welds have already reached their maximum productivity. Moreover, only the location of the electrodes with the lagging arc on the web of the fillet joint can provide better formation of the weld with a slight increase in the size of their legs. Obviously, a further increase in the productivity of the welding of fillet welds with the formation of legs of increased size only possible by using more complicated special techniques, such as multi-arc and multi-electrode welding methods [9], granular iron metal additives or metal powder, other unconventional technologies.

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